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POWER SUPPLIES UNLIMITED

CR-LINE

NJE CORPORATION Kenilworth, New Jersey

INSTRUCTION MANUAL
FOR
CR-LINE

TRANSISTORIZED REGULATED

POWER SUPPLY

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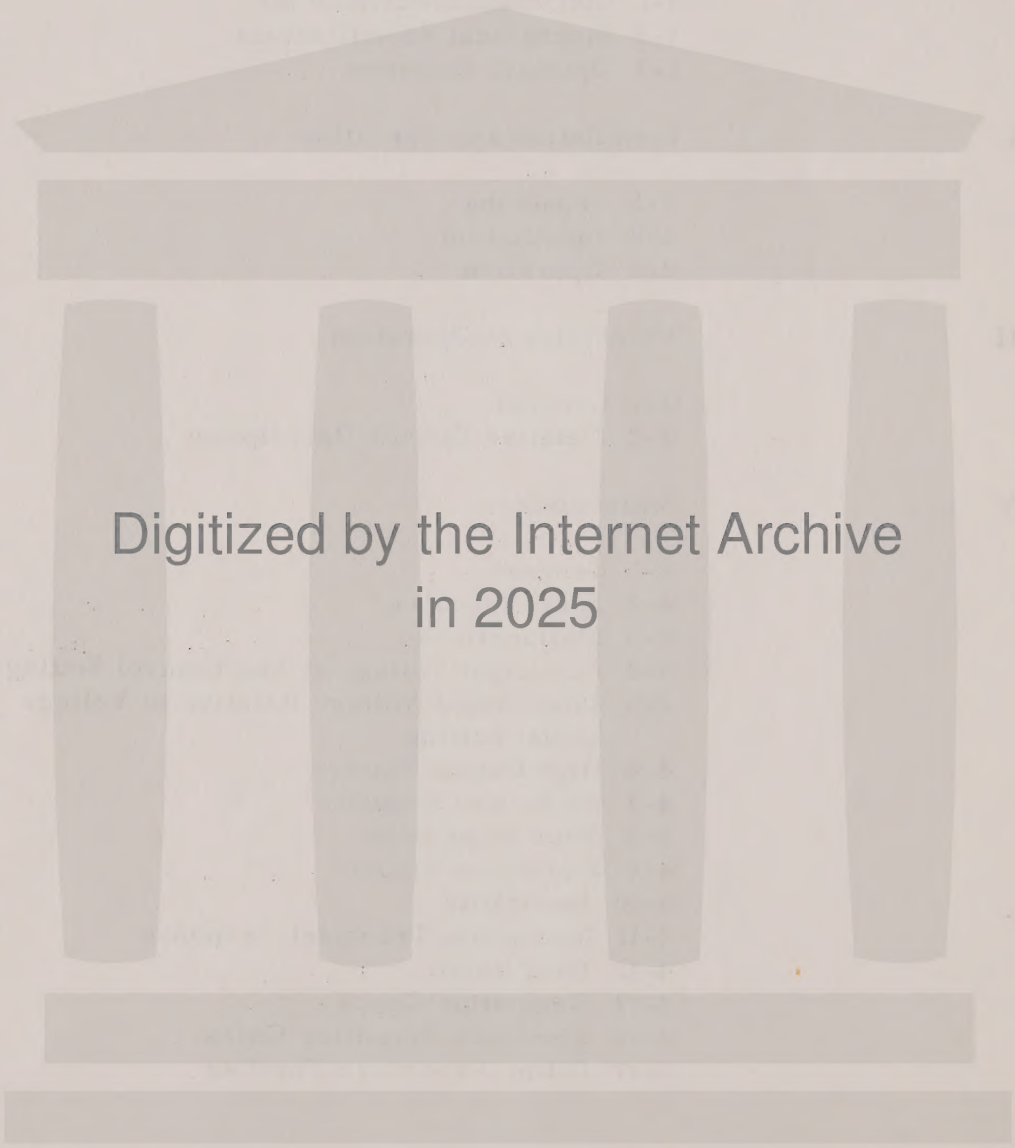
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SECTION I

SPECIFICATIONS AND DESCRIPTION

1-1. ELECTRICAL SPECIFICATIONS

Input:

Model	Volts	Line Current	Power Factor
E/CR 18-30	105-125 55-65 CPS	10A	0.7
E/CR 36-8	105-125 55-65 CPS	5.6A	0.7
E/CR 36-15	105-125 55-65 CPS	11A	0.7
E/CR 36-20	105-125 55-65 CPS	15A	0.7
E/CR 36-30	105-125 55-65 CPS	19A	0.7
E/CR 36-50	187-229 198-242 55-65 CPS	20A	0.7
E/CR 60-9	105-125 55-65 CPS	11A	0.7
E/CR 60-18	105-125 55-65 CPS	21A	0.7

Output: Continuously adjustable by a front panel ten turn potentiometer.

Model	Volts	Amperes	Resolution
E/CR 18-30	0-18 [2]	0-30	3MV
E/CR 36-8	0-36	0-8	5MV
E/CR 36-15	0-36	0-15	5MV
E/CR 36-20	0-36 [1]	0-20	5MV
E/CR 36-30	0-36 [2]	0-30	5MV
E/CR 36-50	0-36 [3]	0-50	5MV
E/CR 60-9	0-60	0-9	7MV
E/CR 60-18	0-60 [1]	0-18	7MV

NOTE 1

Preload of 1 ampere required for operation of 0-6 VDC.

NOTE 2

Preload of 1.5 amperes required for operation of 0-3 VDC.

NOTE 3

Preload of 3.0 amperes required for operation of 0-6 VDC.

Polarity: The output can be floated up to 500 volts peak above or below ground. Either polarity may be grounded to chassis.

Ripple: Total ripple will not exceed 1 millivolts rms.

Load Regulation:

Model	Static Load Regulation No Load to Full Load.
E/CR 18-30	± 0.01% or ± 1MV [1]
E/CR 36-8	± 0.01% or ± 1MV [1]
E/CR 36-15	± 0.01% or ± 1MV [1]
E/CR 36-20	± 0.01% or ± 1MV [1]
E/CR 36-30	± 0.01% or ± 1MV [1]
E/CR 36-50	± 0.01% or ± 1MV [1]
E/CR 60-9	± 0.01% or ± 1MV [1]
E/CR 60-18	± 0.01% or ± 1MV [1]

NOTE [1]

Whichever is greater

Line Regulation: All models; ± 0.02% or 1.0MV; whichever is greater, for slow or step line changes of ± 10%, at constant load.

Recovery Time: The output voltage will remain within the regulated region for instantaneous, prolonged steps of the line voltage of ± 10V. The recovery time for a no load to full load step change (or full load to no load) will not exceed 25 microseconds (except on model CR 36-50; 50 microseconds).

Derating: These supplies are rated for continuous duty over a temperature range from 0°C to 45°C. For service in higher ambient temperatures, the current rating must be reduced linearly to zero current at 80°C.

Remote Programming: This circuit has a sensitivity of about 140 ohms per volts. "Remote Program" terminals are provided. By varying the remote resistance in series with these terminals, the output voltage may be accurately controlled from zero to rated voltage.

Meters: Two rectangular 2% meters are furnished installed on the front panel.

Model	Ammeter Range	Voltmeter Range	Meter Size
E/CR 18-30	0-30A	0-20V	3-1/2
E/CR 36-8	0-10A	0-40V	3-1/2
E/CR 36-15	0-20A	0-40V	3-1/2
E/CR 36-20	0-20A	0-40V	3-1/2
E/CR 36-30	0-30A	0-40V	3-1/2
E/CR 36-50	0-60A	0-40V	3-1/2
E/CR 60-9	0-10A	0-80V	3-1/2
E/CR 60-18	0-20A	0-80V	3-1/2

NOTE

The E/CR models are furnished less the meters.

1-2 Mechanical Specification:

Model	H. in.	W. in.	D. in.	Net Weight	Shipping Weight
E/CR 18-30	7	19	16-5/8		105
E/CR 36-8	3-1/2	19	16-5/8		75
E/CR 36-15	5-1/4	19	16-5/8		90
E/CR 36-20	7	19	16-5/8		105
E/CR 36-30	8-3/4	19	16-5/8		120
E/CR 36-50	17-1/2	19	16-5/8	200	250
E/CR 60-9	5-1/4	19	16-5/8		90
E/CR 60-18	8-3/4	19	16-5/8		120

Mounting: Suitable for laboratory bench use, or for 19" rack mounting.

Finish: Exterior: Finish is smooth dark gray, panel has white trim.
Interior: Metal work has appropriate paint, plating, or anodizing.

Termination: A barrier type terminal strip, at the rear of the unit provides terminals for input, output, remote sensing, remote programming, dualling, and ground. On model CR 36-50, the output terminals are two 1/4-20 studs located on the rear of the unit.

Dualling Operation: Two or more similar units may be operated in series to provide higher voltages at rated current, or in parallel to provide higher currents at rated voltage, (See section II for instructions).

Circuitry: Completely solid state. Silicon power rectifiers, silicon zener diode reference, germanium control and power transistors, all well-derated, characterize the quality and dependability of this supply.

Special Notes: Model CR 36-8 is convection-cooled. A high efficiency heat sink eliminates the need for blowers. Models CR 18-30, CR 36-15, CR 36-20, CR 36-30, CR 36-50, CR 60-9 and CR 60-18 are forced air-cooled by means of internal blowers. Do not block air flow.

Stability: ± 0.05% or 2MV for 24-hour day at loboratory conditions.

Overload Protection: Variable electronic current limiting, by front panel control, adjusts maximum output current over the range, of 10% to 110% of supply rating, thus protecting power supply and load against accidental overloads.

Power Supply Protection: In case of internal faulure within the power supply itself, a slow blow fuse will remove it from the input lines within one minute.

Remote Sensing: Sensing terminals, separate from the output terminals, are provided in order that the unit may "sense" and regulate against, the voltage at the load rather than the voltage at the output terminals.

Front Panel Elements: The front panel elements consist of rectangular output voltmeter and ammeter of 2% accuracy, an AC on-off switch, output voltage adjust knob, a red pilot lamp to indicate application of AC input power, and a current limiting adjust knob.

Rear Panel Elements: AC line fuse or fuses in extractor posts, output, input & control terminal strip.

Environmental Conditions: This power supply will operate satisfactorily over the entire temperature range from + 50° F to 120° F, with humidity up to 90% at altitudes up to 10, 000 feet, without derating.

Assembly: The power supply chassis assembly has an over-all width of 17 inches, and is mounted on a standard 19-inch relay rack panel. Components are mounted on sub-chassis which are secured between two side frames. This construction permits a free flow of air among the components, to facilitate dissipation of heat by the internal forced air-cooling and/or by convection radiation. The unit is designed for installation in a standard relay rack or cabinet, as well as, for use as a bench instrument. It is equipped with a perforated metal cover which serves to protect both equipment and user during operation. All input, output, and control connections are available at the rear of the unit. Two chassis ground connections are included. A barrier type terminal strip contains the following connections:

AC input
AC input
Remote control
Remote control
Dualling
Dualling
Positive sensing
Positive output
Positive capacitor
Negative capacitor
Negative output
Negative sensing

1-3 Optional Features:

50 cps or 400 cps models are designated by suffix 50 or 400 on model number.

Bench Adapter: available for models up through 8 3/4" high, suffix B is added to model number.

Power Cord: All 3 1/2" and 5 1/4" models available with power cord, suffix P is added to model number.

Reverse Voltage Protection: For optimum series operation, the addition of protection diode in output is recommended, suffix S is added to model number

SECTION II

INSTALLATION AND OPERATION

2-1. UNPACKING: The power supply is shipped in a cardboard carton which is floated on sufficient insulation in a heavy-duty shipping carton or crate. The cartons should be retained until it is ascertained that the unit has not been damaged in shipment. If return of the instrument is necessary for any reason, it should be repacked in these original shipping cartons before return to NJE.

2-2. INSTALLATION: The supply can be mounted in any convenient location for bench use, and requires no adjustment or modification for such application. However, bench adapter panels are available from NJE making a neater assembly for bench use. If the unit is to be installed in a housing, it is recommended that the rack or cabinet used be equipped with angle brackets, shelves, or slides to receive the unit, rather than suspending the assembly by its front panel mounting screws. The panel notching is spaced for standard relay rack mounting.

CAUTION

DO NOT OPERATE SUPPLY WITH SENSING LEADS UNCONNECTED. This unit is equipped with separate output-sensing terminals, which have been jumpered directly to the output terminals of the supply. If regulation of the voltage at a remote load is desired, the jumpers must be removed; and the sensing terminals connected directly to the remote load terminals (observing polarity) by means of separate shielded leads.

2-2.1 Connections: When the unit has been placed in position, or mounted in its rack and secured in place by the panel screws, make the following connections.

Item 1. Output Grounding: Using No. [illegible] wire, connect either the positive (TB1-8) or negative (TB1-11) DC output terminal of the supply (depending upon desired output polarity) directly to the chassis ground terminal on the rear of the chassis. On model CR 35-50 the positive output terminal is (8) & the negative output terminal is (11). Number 10 AWG wire should be used for this connection on model CR 35-50. Then connect the ground terminals to the system ground. If it is necessary that the power supply circuit float above or below ground, the output terminal should be connected to the chassis ground terminal by a 0.1 microfarad, 500 V VDC capacitor in place of the direct connection. Use of this by-pass capacitor will improve the stability of the circuit in the ungrounded condition, and reduce the effect of external interference and hum.

Item 2. Output Connections: Connect the positive and negative output terminals, (TB1-8) and (TB1-11) respectively, to the terminals of the external load, using wire of appropriate current carrying capacity for the unit in question (See table below). Plastic or teflon coated wire is recommended. On model CR 36-50 the positive output terminal is (E1) and the negative output terminal is (E5).

Model	Wire Size (AWG)
CR 18-30	10
CR 36-8	1[illegible]
CR 36-15	14
CR 36-20	12
CR 36-30	10
CR 36-50	[illegible]
CR 60-8	1[illegible]
CR 60-15	14

Item 3. Remote Sensing: Connect the positive sensing terminal (TB1-7 or TB2-1 on model CR 36-50) to the positive terminal of the load, and the negative sensing terminal (TB1-12 or TB2-2 on model CR 36-50) to the negative terminal of the load. A shielded pair of No. 20 AWG or larger wire should be used for these connections, or ripple may increase. If accurate regulation at the load is not essential, then the sensing leads may be connected directly at the power supply output terminals; i. e. jumper (TB1-7 or TB2-1 on model CR 36-50) to (TB1-8 or E1 on model CR 36-50) and jumper (TB1-11 or E5 on model CR 36-50) to (TB1-12 or TB2-2 on model CR 36-50).

Item 4. Output Capacitor Connections: The power supply has been shipped from the factory with the POS CAP terminal (TB1-9 or E2 on model CR 36-50) jumpered to POS OUT terminal (TB1-8 or E1 on model CR 36-50) and NEG CAP terminal (TB1-10 or E4 on model CR 36-50) jumpered to NEG OUT terminal (TB1-11 or E5 on model CR 36-50). This connection is satisfactory for most applications. However, if improved transient and dynamic characteristics are required, using a remote load, the POS CAP and NEG CAP terminals should be connected to the remote load on separate leads of the same wire guage as the output leads. Further improvement can be effected by using an independent capacitor (available from the factory) mounted physically as close to the ultimate load as is practical.

Consult the NJE Engineering Dept. on special transient problems.

Item 5: Remote Control-Programming: Terminals (TB1-3 or TB2-3 on model CR 36-50) and (TB1-4 or TB 2-4 on model CR 36-50) are provided for the insertion, in series, of a remote control programming resistor. This circuit has a sensitivity of about 140 ohms per volt. When the the panel voltage adjustment knob is set to zero, the output voltage may be accurately controlled from zero to rated voltage by varying the programming resistance. The programming resistance should never be allowed to become greater than 140 x the output voltage of the unit. The remote programming terminal must never become open circuited even for periods as short as 50 micro-seconds; otherwise, damage to the unit or external load may result.

Item 6: Dualling: Two supplies may be operated in parallel (with an overall current derating of 10%) or in series. Consult the Dualling Schematic of Figure 2-2 for proper interconnection and wiring of the individual supplies and the load.

Item 7: Input Connections: Connect the deactivated input line (115 volts nominal, 60 cycles, single phase) to the AC input terminals (TB1-1)and TB1-2 or TB1-3 on model 208/220 for model CR36-50) using wire of appropriate current carrying capacity for the unit in question, (see table below). Plastic or teflon coated wire is recommended.

Model	Wire Size (AWG)
CR 18-30	16
CR 36-8	18
CR 36-15	16
CR 36-20	14
CR 36-30	14
CR 36-50	10
CR 60-9	16
CR 60-18	14

Controls:

1. Fuse or fuses (AG) & (BE) are located on the rear surface of the power supply.
2. The overload current adjust potentiometer (AF) is located on the front panel.

3. The ON-OFF switch with the input power indicator panel lamp is located on the front panel.

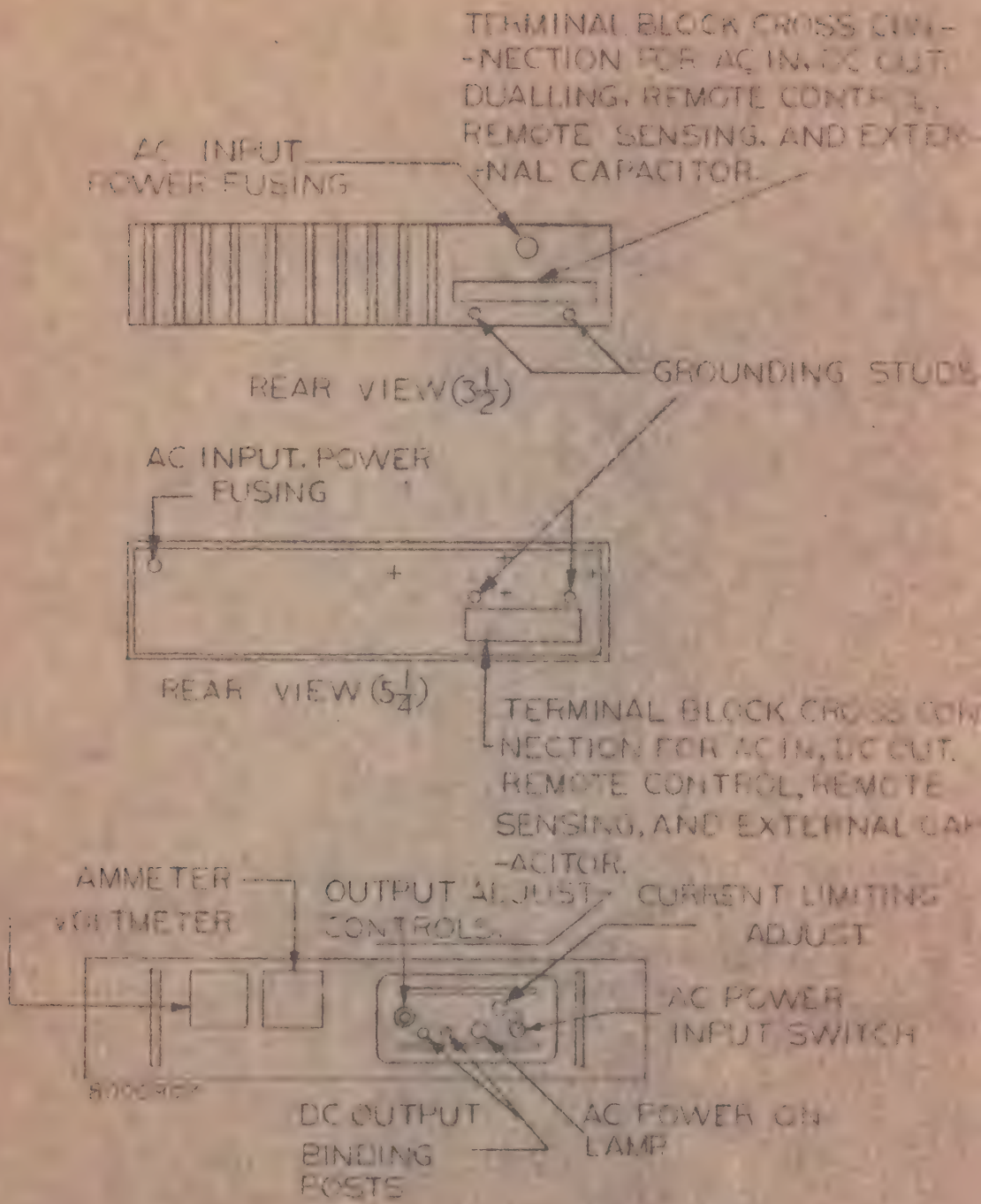
4. The output voltage control knob (or knobs on ECR models) is located on the front panel.

5. The voltage and current indicating meters are on the front panel.

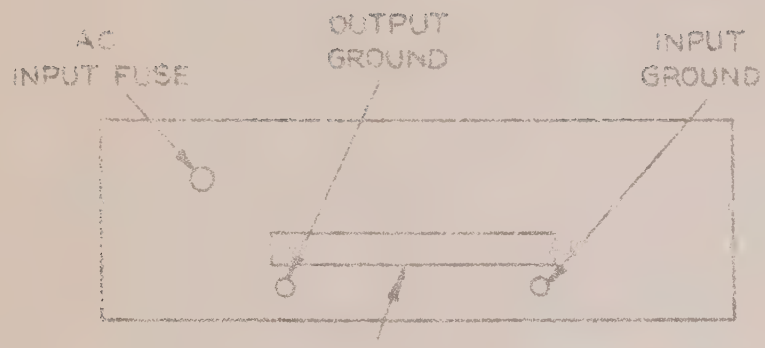
6. The terminal strip located in the rear of the unit contains termination for input voltage, output, remote sensing, remote programming, and dualling. On model CR 36-50 additional heavy duty 1/4-20 studs are provided for output connections.

7. Input and output ground terminals are located at the rear of the unit.

2-3. Operation: Set the AC control switch in OFF (open) position and energize the AC input line. Set the OUTPUT ADJUST control to full counterclockwise position, then place the AC control switch in the ON position. The indicator on the front panel should light. Observing the panel voltmeter, adjust the load voltage to the desired value, by means of the OUTPUT ADJUST. Check the load current meter to avoid overload conditions. If the required voltage value cannot be achieved, de-energize the input line and check connections on the rear terminal strip before referring to the troubleshooting section of this manual. To use the Variable Current Limit Feature, set the front panel Current limit potentiometer to the current desired by means of calibration curve Figure 2-3 or as follows: Load the power supply to the desired current at which limiting is required, then back off Current limit potentiometer until output voltage starts to fall off, then rotate current adjust potentiometer a few degrees clockwise. Variable Current Limiting accomplished by means of circuitry of A3 and current adjust potentiometer (AF).

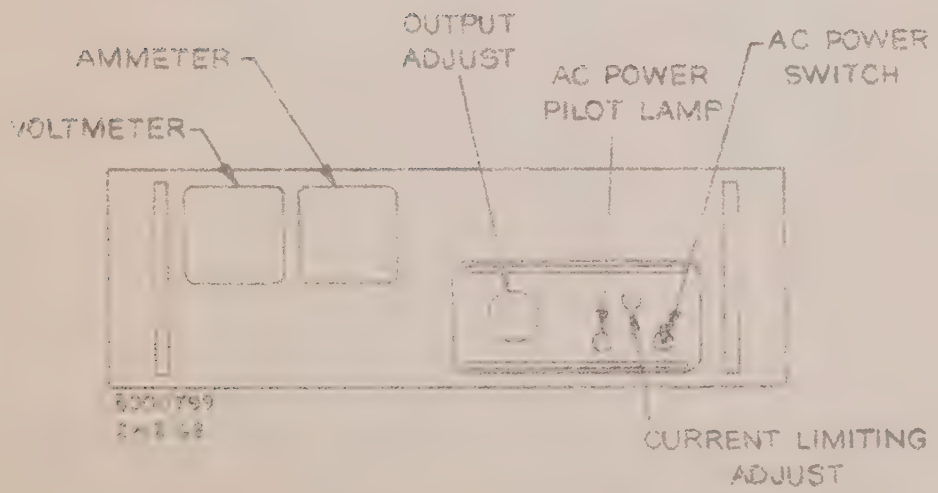

TERMINAL BLOCK CROSS CONNECTION FOR AC IN, DC OUT, DUALLING, REMOTE CONTROL, REMOTE SENSING, AND EXTERNAL CAPACITOR.
AC INPUT POWER FUSING
REAR VIEW (3 1/2)
GROUNDING STUDS
AC INPUT. POWER FUSING
REAR VIEW (5 1/4)
TERMINAL BLOCK CROSS CONNECTION FOR AC IN, DC OUT, REMOTE CONTROL, REMOTE SENSING, AND EXTERNAL CAPACITOR.
AMMETER
VOLTMETER
OUTPUT ADJUST CONTROLS
CURRENT LIMITING ADJUST
AC POWER INPUT SWITCH
DC OUTPUT BINDING POSTS
AC POWER ON LAMP

OPERATIONAL ELEMENTS AND CROSS CONNECTION FIG. 2-1A



TERMINAL BLOCK CROSSCONNECTION
FOR INPUT, RMTE SENS, DUALLING,
EXT. CAP., OUTPUT.

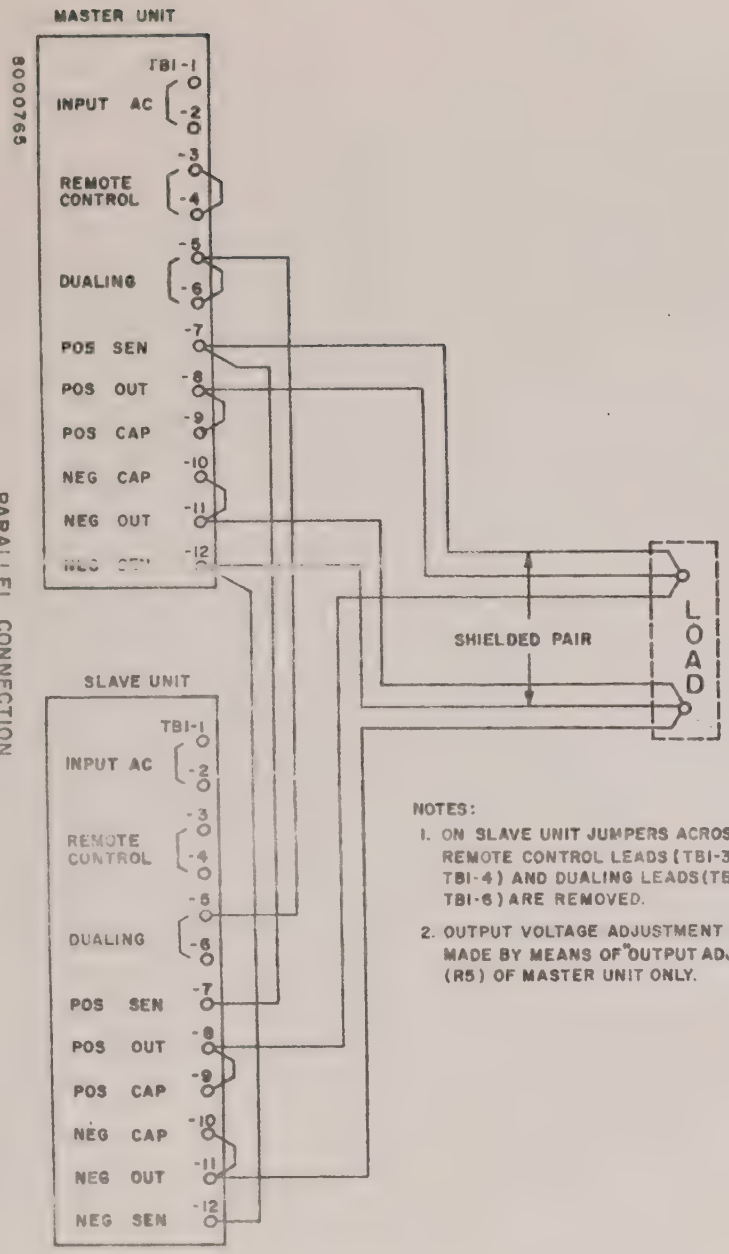
REAR VIEW



FRONT VIEW

OPERATIONAL ELEMENTS

FIG. 2-1B



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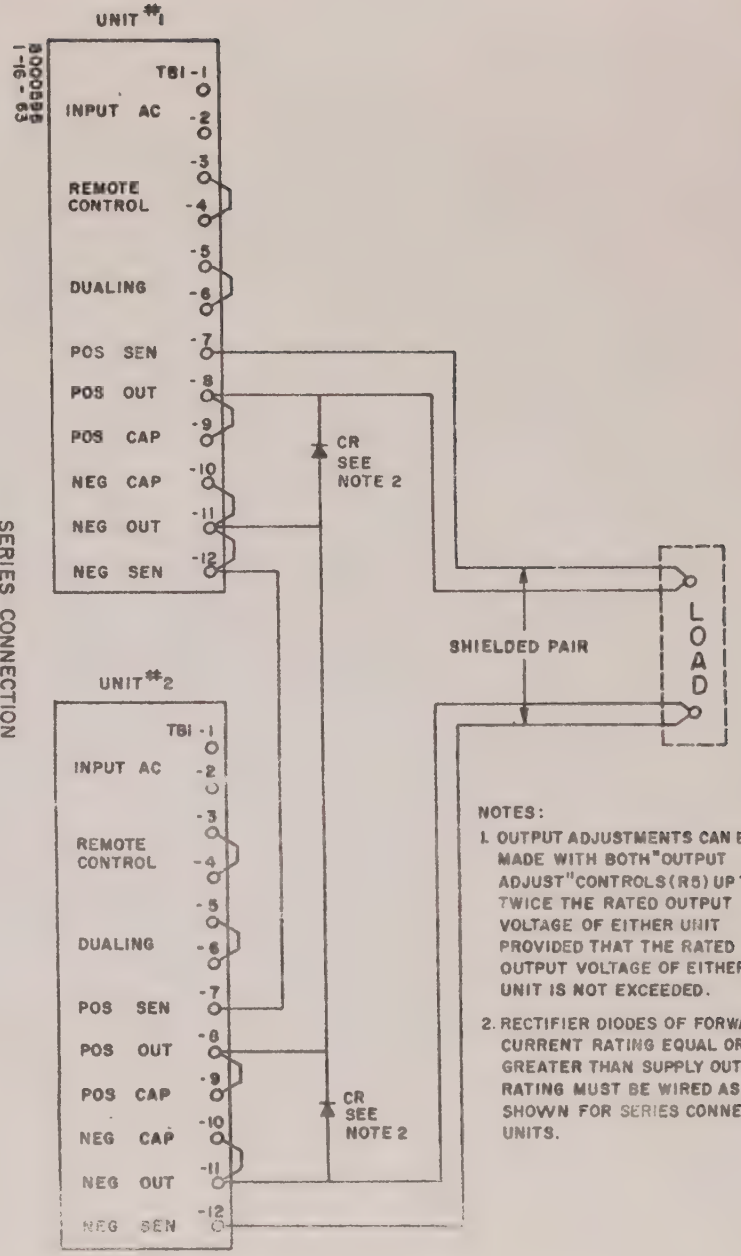
PARALLEL CONNECTION

FIGURE 2-2B

NOTES:

1. ON SLAVE UNIT JUMPERS ACROSS REMOTE CONTROL LEADS (TBI-3 & TBI-4) AND DUALING LEADS (TBI-5 & TBI-6) ARE REMOVED.
2. OUTPUT VOLTAGE ADJUSTMENT IS MADE BY MEANS OF "OUTPUT ADJUST" (R5) OF MASTER UNIT ONLY.



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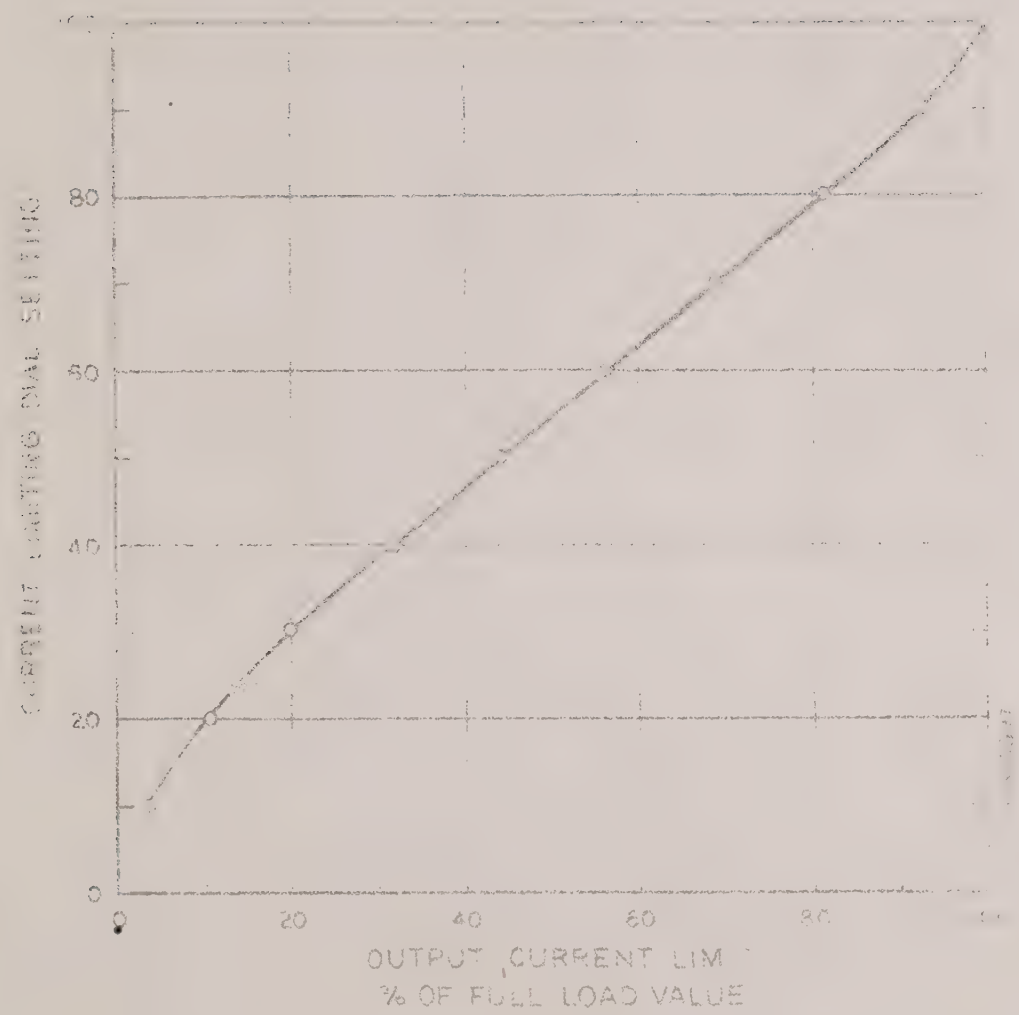
SERIES CONNECTION

FIGURE 2-2A

NOTES:

1. OUTPUT ADJUSTMENTS CAN BE MADE WITH BOTH "OUTPUT ADJUST" CONTROLS (R5) UP TO TWICE THE RATED OUTPUT VOLTAGE OF EITHER UNIT PROVIDED THAT THE RATED OUTPUT VOLTAGE OF EITHER UNIT IS NOT EXCEEDED.
2. RECTIFIER DIODES OF FORWARD CURRENT RATING EQUAL OR GREATER THAN SUPPLY OUTPUT RATING MUST BE WIRED AS SHOWN FOR SERIES CONNECTED UNITS.



ADJUSTING CURRENT LIMITING CONT

SECTION III

PRINCIPLES OF OPERATION

3-1. GENERAL: A simplified block diagram illustrating the basic elements of the circuit and the signal flow, is shown in Figure 3-1. The AC line voltage is transformed to adequate values to supply the Rectifiers and Controlled Rectifiers through the main transformer . The firing circuit and transistor amplifier voltages are obtained from the auxiliary transformer and an associated AC to DC rectifier and filter system. On some models, the main and auxiliary transformers are one unit with separate windings, See Figure 3-1. The average value of the signal from the SCR is filtered by a capacitor input filter. The control of the average voltage across the capacitor input filter is accomplished by control of the firing point of the SCR, and will be discussed later. The output voltage furnished to the load by the series regulator is monitored by a feedback amplifier, which compares this voltage with a stabilized reference voltage, and amplifies the difference between the two voltages. The output of the amplifier is used to control the series regulator in such a way that it counteracts any change in the DC output voltage, thereby furnishing an essentially constant voltage to the external load. The controlled rectifier is basically a device which controls the magnitude of average DC voltage at the capacitor input filter in such a way as to maintain the storage voltage across the series regulator within its dissipation capabilities.

3-2. DETAILED CIRCUIT DESCRIPTION. Circuit references in the following material apply to the schematic diagram at the back of the manual. This diagram shows electrical relationships, and is laid out in an arrangement approximately the same as that of the Block Diagram, Figure 3-1.

3-3. The power supply is energized by connecting 115 volts (nominal) 60 cycles, single-phase (208 or 220V on model CR 36-50), to the input terminals (TB1-1 & TB1-2 & TB1-1 & TB1-3 on model CR 36-50), and closing switch (S1), attested by the lighting of pilot lamp (DS1).

3-4. The power transformer winding (S) converts the input line voltage to an appropriate value, which is rectified to a pulsating DC output voltage by rectifier assembly (AA) and (L). This DC voltage is then filtered by capacitor (C1), and applied through a regulating transistor assembly (A) to the external load. Capacitor (B) provides additional filtering of the output, and reduces the internal impedance of the supply for medium frequency load variations.

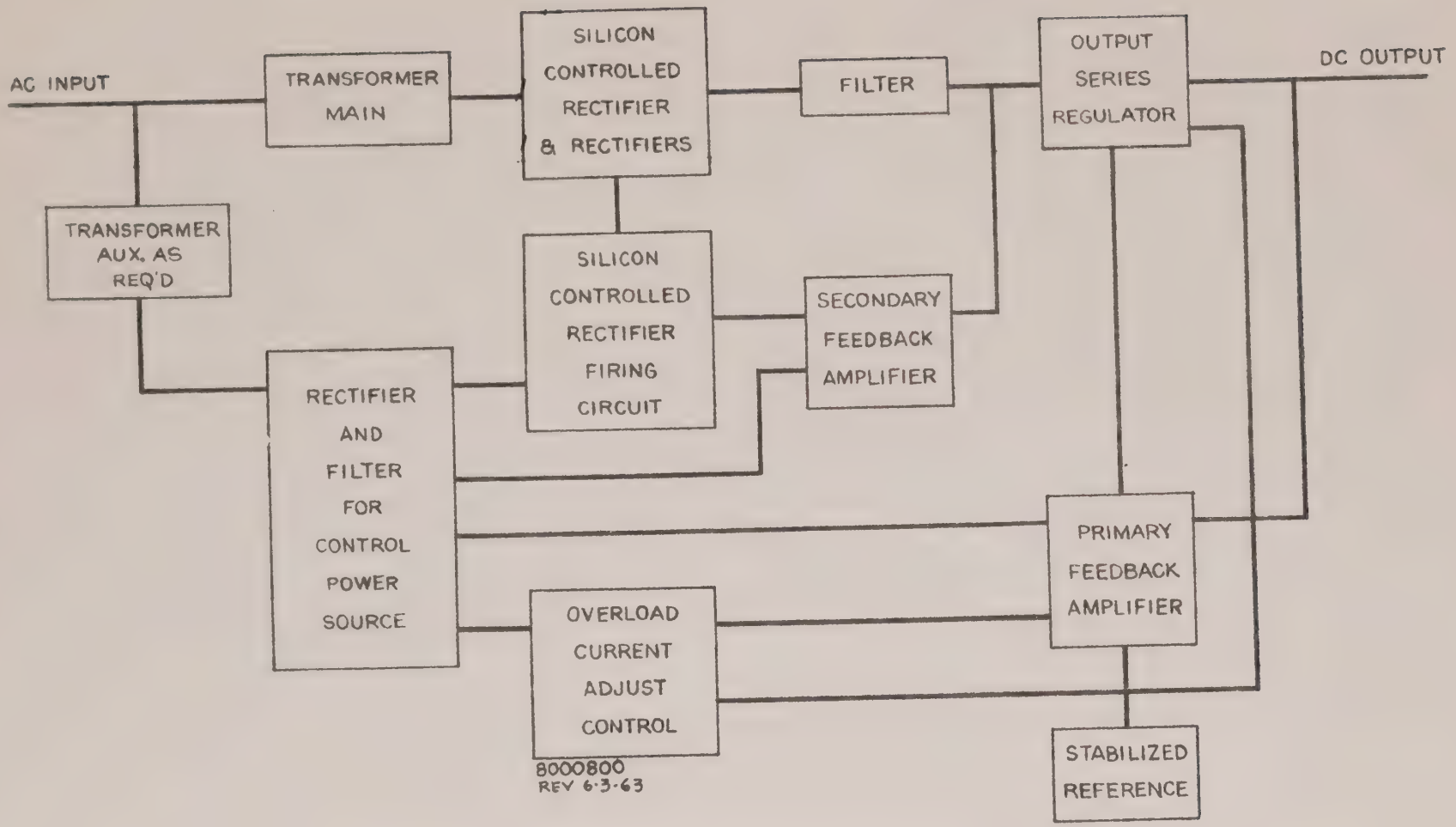
3-5. The output voltage on the auxiliary winding (W) is rectified by diodes (CR101 and CR102) and (CR103 and CR104), and filtered by capacitor input filter (C102)-(AK) to provide positive and negative operating potentials for the feedback amplifier. Zener diode (CR109), in conjunction with its load resistor (C), provides regulated + 18 VDC: while diode (CR110) with resistor (D) provides -18 VDC (measured with respect to the negative output terminal of the unit. These zener diodes function in a manner analogous to that of a gaseous voltage regulator tube, providing a relatively constant output voltage across their terminals despite variations in the conducted current. Transformer winding (U) feeds (A2), the controlled rectifier firing circuit. The function of this circuit will be described later.

3-6. The feedback amplifier consists of three stages of amplification; the first two of which are balanced amplifiers, assuring minimum sensitivity to fluctuations in ambient temperature or operating voltages. The input signal for the amplifier is derived from a voltage sensing divider connected acorss the output, of the supply. This divider consists of resistors (E) and (F) in the amplifier, and resistor (G) on the main chassis. The resistance setting of (G) determines the operating value of the DC output voltage of the supply in a manner which will be explained below. Resistor (G) is connected to the output voltage control knob on the front panel. (F101) at the base of (Q108) provides protection for both the precision feedback resistor (G) as well as the transistor differential amplifier during surges arising because of transient load conditions.

3-7. The negative end of the sensing voltage divider (negative end of resistor) (E) is returned to the negative output of the supply through zener diodes (CR111) and the negative sensing lead. The diode, in conjunction with its load resistor (H), provides a highly stable potential of 6 VDC for use as a comparison voltage by the input stage (Q 107 & Q 108) of the feedback amplifier. When the output of the power supply (measured at the load) is precisely at its selected nominal value, the voltage at the same level as the base of transistor (Q107); and the input stage is in balance. Under this condition, any tendency of the load voltage to vary in either direction will unbalance the amplifier, resulting in corrective action which compensates for the impending change; and holds the load voltage at its established value, as explained below.

3-8. Transistors (Q107 and Q108) are PNP type units, operated in common-emitter mode, and connected as a balanced differential amplifier. Their outputs, taken across load resistors (I) and (J) are direct-coupled to the bases of the succeeding differential amplifier stage (Q105)-(Q106), which consists of two NPN transistors operated in common-emitter mode. The output of (Q105), from its load resistor (AD), drives the base of the single ended output stage (Q104). The output of the amplifier is tied directly to the base of the driver transistor (Q101) On model CR 36-50 an additional stage of gain is provided by transistor (BC). In this case, the output of (Q101) is tied to the base of transistor (BC).

3-9. Regulation of the DC output is performed by a double regulating system. A transistor series regulator consisting of power transistors (A), operating in parallel, provides high-speed regulating action to correct for ripple and transient variations both at its input (AE-AE) and at the output of the supply. The amplifier loop which provides correction signals to the series regulator is driven directly from the output through the feedback resistor divider and is comprised of transistor (Q103, 107, 106, 105, 104 and driver transistor Q101) on model CR 36-50 transistor (BC) is added.
A silicon controlled rectifier (L), which is driven by the components of (A2), is designed to regulate the "storage" voltage across the series regulator. The circuit is such that regardless of the output load requirement, the power dissipation of the series transistor regulator is maintained within its rating.



FUNCTIONAL BLOCK DIAGRAM

FIG. 3-1

3-10. The controlled rectifier firing circuit (A2) senses the current through the pass transistor (A), as well as, the voltage across the pass transistor, to adjust the storage voltage of the pass transistor by controlling the average value of the voltage across (AE-AI). The feedback circuit consists of (Q) and (M) and (N). (Q) is a measure of the load current, while (M) is a measure of the storage voltage; and the circuit is designed to limit the maximum dissipation in the series regulator on some models (Q) is not used. Voltage appearing at the junction of (Q, M and N) is fed to the base of transistor (Z) which drives the controlled rectifier firing circuit (A2) on some models, transistor (Z) is not used (see schematic diagram at the end of this manual). In this case, the voltage appearing at the junction of (Q, M and N) is fed directly to terminal No. 5 of the controlled rectifier firing circuit (A2) in this type of unit terminal No. 4 of the controlled rectifier firing circuit is tied directly to the negative output terminal of the unit. The voltage at the base of (Z) controls the current to the controlled rectifier firing circuit (A2), terminals 4 and 5. The current flow through terminals 4 and 5 determines the firing point of the controlled rectifier as explained below. Thus, a change in the voltage across the pass section triggers the silicon controlled rectifier in such a manner as to change the average voltage at (AE-AB), so that the power dissipation in the pass section is maintained at a safe operating level. The operation of the firing circuit (A2) is accomplished in a novel way to achieve a wide range of firing control of the SR gate. This control is from approximately 15° to 165° of each half cycle. The firing point is varied by setting the level of the base current of (Q2). The method of creating the firing pulse is by switching (Q4) on and off. This is accomplished with the following sequence of events; (C2) acts as the storage capacitor to set the bias levels for (Q1) (Q3) and (Q4). (Q1) conducts and charges (C1) when the emitter of (Q1) is more positive than the voltage at the base. The transformer winding and rectifier and the combination of (CR3) and (R1) allows the emitter to go positive at some point during the pulsating voltage. The current flow through (Q1) charges (C1). As (C1) discharges through (Q2), the base of (Q4) will be at approximate negative voltage to switch (Q4) to the conducting state. The discharge of (C1) through (Q2) is controlled at the rate determined by the effective resistance presented to the discharge current. Therefore the full range of firing is controlled by the relatively small base current of (Q2). The switching on of (Q4) is controllable through almost all of the half cycle. The switching off is made rapid with the charge of (C3) establishing a voltage sufficient to switch off (Q4). The pulse thus established is transmitted to the controlled rectifier through pins 6 and 7 of (A2). Storage voltage control of series regulator (A) is achieved in the following manner. Suppose the Output Adjust (G) is varied to produce a reduced output voltage. Since the series regulator's response is much faster than the controlled rectifier, a momentary situation develops in which the series regulator voltage increases i. e., the voltage (AE-AE) holds momentarily while the output voltage is reduced. As described above, when the series regulator voltage increases, the storage regulator amplifier loop causes the controlled rectifier output to restore the original series regulator voltage. In this case, the voltage at (AE-AE) drops to compensate for the output voltage reduction. It is thus seen, that the controlled rectifier output (AE-AE) tends to 'track' the output voltage; and in this manner maintains the series regulator dissipation within fixed limits.

Storage Voltage: Storage voltage is a measure of the voltage across the series regulator transistor (A). It varies only slightly with various line and load conditions on the power supply. It is adjusted by activating the power supply by means of (S1) and then adjusting first the no load storage adjust (Q) and then the full load storage adjust (M). A preset value of input voltage to the unit and its output voltage adjustment setting for this test follows in a table for all CR type units. "Full Load" means that the supply is loaded, by means of a dummy load to its maximum output current capabilities.
The storage voltage adjustment need never be touched unless (CR109), Resistor (W), or transistor (Z) are replaced. If any or all of these parts are replaced on the unit, then the storage voltage should be checked from the table and re-adjusted if needed.

STORAGE VOLTAGE TABLE

Model No.	Storage Voltage No load (adj, Q)	Storage Voltage Full load (adj, M)	Input Line Voltage	Unit Output Voltage
CR18-30	5.0-5.5VDC	4.0-4.2VDC	105 VAC	18 VDC
CR36-8	None	4.3-4.7 VDC	115 VAC	36 VDC
CR 36-15	None	6.4-6.7 VDC	115 VAC	36 VDC
CR 36-20	7.2-7.7 VDC	2.9-3.3 VDC	105 VAC	36 VDC
CR 36-30	None	5.5-6.1 VDC	115 VAC	36 VDC
CR 36-50	None	5.2-5.7 VDC	208/220 VAC	36 VDC
CR 60-9	None	9.8-10.2 VDC	105 VAC	60 VDC
CR 60-18	None	5.9-6.2 VDC	115 VAC	60 VDC

3-11. The regulating principle through the series regulator feedback circuit is to maintain balance at the bases of (Q107 and Q108). These bases will maintain balance within a small voltage which is the error voltage due to feedback loop gain level. Due to the high gain of the system, the error voltage will be small, and at maximum, equal to the maximum allowable error of the equipment. The sequence of operation is by adjustment of (G) or any change in current through (G). Either change will unbalance the base of (Q108) with respect to (Q107) base. The system will adjust itself up or down until the voltage level at both bases are equal. Any load or line change will unbalance the amplifier and require corrective action. One such action will be described. The other disturbances cause the circuit to react in a similar manner. If we wish to raise the output voltage, then the value of (G) is increased. This increase decreases the voltage at the base of (Q108). The error is amplified through the system and a signal is applied to the base of the series regulator transistor (A) in such a manner as to decrease its storage voltage. The controlled rectifier at the same time raises the average level at (AE-AB). The rise in the output was such that the voltage at the output terminals divided by the value of (G) is equal to the zener voltage (CR111) divided by (E) and (F).

3-12. The sensitivity and speed of response of the corrective feedback circuit is such that the above-described action occurs almost instantaneously and the actual excursion of the load voltage is held to a very small value. The circuit is a true proportional regulator, and must allow a small but finite "error" to exist between the required and actual regulated voltage, so that this error, however small, can generate the correction signal. By proper circuit design, however, the error is held to a value which remains within the specified regulation allowance of the power supply.

3-13. When resistor (G) is readjusted to produce a different value of output voltage, the circuit makes a correction similar to that described above. Altering the resistance in the sensing voltage divider unbalances the input stage of the feedback amplifier, which then causes the circuit to produce a new value of voltage such that the drop across resistors (E-F) again equals the drop across diode (CR111). Reducing the value of resistor (G), for example momentarily increases the drop across (E-F). However, this unbalanced condition at the amplifier input causes the DC output voltage to decrease until the drop across (E) and (F) again equals the drop across (CR111); and the circuit stabilizes at this new operating point, establishing a lower value of DC output voltage. See description of corresponding storage regulator action in paragraph 3-10.

3-14. Resistor (F) in the amplifier is provided to permit compensation for manufacturing tolerances in diode (CR111), its load resistor (H) and resistor (E). This resistor (F) is adjusted at the factory (and locked). If any of these components are replaced, check to see that full rated output voltage of the supply is obtainable at full load, with the voltage control at maximum clockwise position, with a line voltage of 105 volts. If not, readjust (F) to provide full output voltage under these conditions.

3-15. Variable Current Limiting is accomplished by means of circuitry of (A3) and Current Limit potentiometer (AF). The overload current limit circuit operates in such a manner as to limit the output current from series regulators (A) to the setting of CURRENT ADJUST (AF). The action of the circuit may be described as follows: (AF) is a voltage divider resistor feeding the base of (Q302). The emitter of (Q302) is connected to the base of (Q101), the main series regulator driver transistor. The voltage level at this point varies with output load current developed across the emitter resistors the series regulator transistors. Thus, when the load current attains a value high enough to cause the voltage at the emitter of (Q302) to drop below the preset base level, transistor (Q302) begins to conduct. This causes current flow through (R301) which then forces (Q301) to conduct. This action effectively clamps the base drive at (Q104) through diode (CR302). The action is quite sharp once conduction begins. Prior to conduction, the diode (CR302) effectively decouples the overload circuit from the main amplifier. The circuitry of (Q303), (CR 301 & CR 303) & (R307 & R308) is provided to protect the series regulators (A) from over dissipation during short circuit when the storage voltage across the series regulators may attain a very high value until the controlled rectifier is able to decrease the average voltage at (AE-AE)

This circuit acts as follows: a voltage divider consisting of resistors (R307) & (R308) is connected between the +18VDC, bias point and the collectors of the series regulators (A). The junction of these resistors is connected to the base of (Q303) whose emitter is tied to the negative output terminal of the supply. If the storage voltage across (A) increases beyond a point determined by (R307) & (R308), transistor (Q303) is turned on. This clamps the base of driver transistor (Q101) to the negative output of the unit cutting off its drive current to the series regulators. This action decreases current flow from the series regulator (A) to a very low value until the controlled rectifier decreases the average value of voltage at (AE-AB). This action keeps the dissipation of the series regulations at a safe value at all times. This circuit overrides the current limiting circuitry during short circuit over load conditions on the output of the power supply, and is designed to protect the series regulators (A).

SECTION IV

MAINTENANCE

4-1. GENERAL: This section is arranged in the form of a trouble-shooting chart, with symptoms listed approximately in accordance with the frequency of occurrance. Possible causes for each, and their remedies, are listed in logical succession beginning with the most common, to facilitate rapid location and isolation of a defective element.

4-2. SPARE MODULES: Where practical, it is recommended that one or more spare printed circuit boards and regulator assemblies be kept available for use in maintenance. This will reduce down-time to a minimum and permit easy testing by direct subsitution, making it possible to repair a defective module at some convenient time and avoid prolonged interruption of operation.

4-3. MALFUNCTIONS: The various ways in which DC power can deviate from normal operation are listed below. Each condition is treated separately in the charts that follow. Component symbol designations refer to the schematic diagram at the rear of the manual. Parts locations are indicated in the parts placement diagrams also included at the rear of this manual.

MALFUNCTION	TYPICAL MAGNITUDE
1. No output voltage at any control setting.	Zero or DC output voltage.
2. Low output voltage.	Maximum output voltage obtainable at no load is less than maximum rating.
3. High output voltage.	Minimum output voltage obtainable at no load is more than maximum rating.
4. Failure to regulate.	Output voltage drops 5% or more when load is applied, for varies ±2% or more under a ±10% variation in line voltage.
5. Poor regulation	Regulation better than above, but not within specification.
6. Excessive ripple.	
A. With good regulation	RMS ripple exceeds specification, but regulation is within specification.
B. With poor regulation	RMS ripple exceeds specification, and regulation exceeds specification.
7. Instability	
A. Random large excursions	Output voltage "hops" intermittently by 5% or more, with constant load, and constant line voltage.

MALFUNCTION	TYPICAL MAGNITUDE
B. Gradual drift in one direction.	Output voltage changes by 1% or more per minute, after a 15-minute warm-up.
C. Excessive drift under heavy load only.	Output voltage changes by 1% or more per minute, after a 15-minute warmup but only after application of a heavy load.
8. Inadequate transient suppression.	Failure to "zero-lag". Upon sudden application of a full-load increase, output voltage dips sufficiently to cause a visible momentary deflection of the voltmeter needle.
9. Oscillation	
A. High frequency	Under constant load, output voltage is modulated by sawtooth or sine-wave with frequency of 200 cycles or more per second.
B. Low frequency	At constant load, output voltage exhibits relaxation modulation at or below 200 cycles per second.

4-4. NO OUTPUT VOLTAGE AT ANY CONTROL SETTING.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Pilot light (DS1) not lit.	1. No line power, or defective input connection.	1. Check power source, lines and connections.
	2. Input fuse or fuses (AG) blown. Control fuse or fuses (BF) blown.	2. Replace fuse. If fuse blows repeatedly, do not overfuse.
B. Repeated blowing of fuses (AG) or (BF).	1. Shorted rectifiers (AA) or (L).	1. Replace rectifier, or rectifiers.
	2. Shorted rectifiers on (A2, CR1 or CR2) or on (A1, CR101, CR102, CR103 CR104).	2. Replace rectifier or rectifiers.
C. Fuse (AG) blown.	1. External	1. Check for overload.
D. Unregulated DC across (AE) zero or low. Fuse (AG) not blown"	1. Open rectifiers (AA) or (L) (CR101, CR102 CR103, CR104, or on A2, CR1 or CR2).	1. Replace rectifiers or controlled rectifier.

NO OUTPUT VOLTAGE AT ANY CONTROL SETTING (cont'd).

SYMPTOM	POSSIBLE CAUSE	REMEDY
	2. Primary or secondary transformer open.	2. Replace transformer.
E. Unregulated DC present at (AE) but more than 15-25% higher than DC output.	1. Entire, or major part of unregulated DC voltage across (AE) absorbed by regulator transistor (A). Caused by short or excessive leakage between base of driver or regulator transistors (Q101) (EC) or (A) respectively and any positive voltage or ground. (For example: If positive output is operated at chassis ground and chassis.	1. Inspec for short. Isolate driver transistor from heat sink & chassis, and operate unit for brief interval. If this restores normal operation, replace driver insulation, and /or driver itself, as necessary. If not cleared, repeat for regulators (A).
	2. Amplifier or sensing circuit defective.	2. Check by momentarily shorting base of collector of (Q101). If DC output is restored, amplifier or sensing circuit is at fault. See end of this Section for amplifier check.
	3. Rate sensing capacitor (AH) shorted internally, or by external wiring short.	3. Inspect for short. Disconnect one terminal of capacitor. If DC output is restored, replace capacitor.
	4. Defective driver transistor. (Q101) also (EC) on model CR 36-50.	4. Check by momentarily shorting base to collector on driver transistor at no load. Replace driver transistor.
	5. Ammeter (M1) open.	5. Check by momentarily shorting meter terminals. Replace.
	6. Resistors (P) all open.	6. Replace. Defective resistors.
	7. On (A2) shorted (C303) or open (R307).	7. Replace Defective components.

4-5. LOW OUTPUT VOLTAGE RELATIVE TO VOLTAGE ADJUST SETTING.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Unregulated DC present at (AE) in expected magnitude (15% to 30% higher than output voltage at nominal line voltage at no load).	1. Amplifier or sensing circuit defective.	1. Check by momentarily shorting base to collector of (Q101). If this restores DC output, check sensing voltage divider. See end of this Section for amplifier check.
	2. Rate sensing capacitor (AH) has excessive leakage.	2. Disconnect one terminal of capacitor. If this restores DC output, replace capacitor.

4-6. HIGH OUTPUT VOLTAGE.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Output voltage adjust knob has little or no control over DC output.	1. External sensing circuit improperly connected. Internal sensing voltage or wiring open.	1. With power off, check continuity of sensing leads, internal sensing circuit from positive output terminals to amplifier input and from negative output terminal to neutral bus of amplifier.
B. Output control effective, driver base (Q101) negative with respect to negative output terminal.	1.a. Bleeder resistor (A1) open, or regulator transistor (A) Ico drain open resistor (AJ) & (JA) or (BE) on model CR 36-50.	1.a. Check by applying full load. If this restores normal operation, check for open resistor or connection.
	b. Defective amplifier	b. See amplifier check at end of this Section.
	c. Defective amplifier power supply.	c. Check voltage across filter capacitor (C102) (C103) or (AK) as shown on schematic diagram. If correct, check resistors (C-N) for open.
		d. If incorrect, check the capacitors, (C102 C103) diodes (CR101 thru CR104) and secondary winding of transformers.
C. Driver base (Q101 positive with respect to negative output terminal.	1. Defective driver and/or pass transistor on model CR 36-50 check transistor (EC) also.	1. Check for shorted transistors.

4-7. FAILURE TO REGULATE.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Load regulation is 5% or more, line regulation 2% or more.	1. a. Defective amplifier	1. a. See amplifier check at end of this Section.
	b. Defective amplifier power supply.	b. Check voltage values of filter capacitors (C103 C102). If incorrect, check the capacitors, diodes (CR101 thru CR104) and main secondary winding of transformer. Check (D) and (C) for open.
	c. Very low performance transistor in regulator or driver circuit.	c. Check for equal voltages across resistors in series with emitter of power transistors, to detect defective transistor, check transistors in a transistor test set or by substitution.
	d. Failure in adjust current limiting circuit.	d. Check transistors first then carefully check other parts for open or shorts & replace any defective components found.

4-8. POOR REGULATION

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Load regulation less than 5%, but not within specification.	1. External sensing circuit incorrectly connected.	1. Check by operating unit with sensing terminals temporarily jumpered to the local output terminals. (Observe correct polarity).
	2. Low gain amplifier.	2. See amplifier check at rear of this Section.
	3. Low beta in driver or power transistors.	3. Check by substitution or in transistor tester Beta of 20 or more is acceptable.
	4. Oscillating amplifier.	4. Check (AL)for proper value. See amplifier check at rear of this Section. on model CR 36-50 check (C5) also.

	b. Filter capacitor (AE) (C102) or (C103) open or of low value.	b. Replace
	c. Note: Ripple at (AE) should not exceed 5%. of maximum output voltage of unit.	c. Replace
	d. Rate-sensing capacitor (AH) open or of low value.	d. Replace
	e. Hum pick-up in external sensing leads.	e. Check by operating unit with sensing terminals temporarily jumpered to local output terminals or external sensing leads.
	f. Low-gain amplifier.	f. See amplifier check at end of this Section.
B. Output regulation poor.	1. a. Low beta in power transistors or driver transistors.	1. a. Check by substitution or in transistor test set. Beta of 20 or more is acceptable
	b. Low gain amplifier.	b. See amplifier check at end of this Section.
	c. Defective amplifier power supply.	c. Check diodes (CR101 thru CR104) for shorts or open capacitors (C102) (C103) for open, low value, or high leakage. Check diodes (CR110 (CR109) and resistors (C) and (D).

4-10. INSTABILITY.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Random large excursions of output voltage.	1. Intermittent failure of component or intermittent short or open in circuit.	1. Check primary power circuit by temporarily connecting base of driver transistor (A) to negative output terminals. If instability persists, check for intermittent breakdown in rectifiers (AA-L) or filter capacitors (AE). Check for intermittent opens or shorts in unregulated DC circuit. Check driver and power transistors in tester, or by substitution. Check for intermittent opens or shorts or defective component from (AE) to output terminals. Look for intermittent open or short, of intermittently defective component in (1) amplifier, (2) amplifier power supply, (3) sensing voltage divider and external sensing circuit and (4) controlled rectifier firing circuit. Check amplifier connector for poor contact. Check rate-sensing capacitor (AH). Check voltage across (CR109, CR110 and CR111) for stability.
E. Grandual drift in one direction at any load, after 15-minute warmup.	2. a. Defective amplifier	2. a. See amplifier check at end of this Section.
	b. Drifiting zeners.	b. Check (CR109), (CR110) and (CR111). Replace if faulty.
	c. Output adjust potentiometer (G) unstable.	c. Replace

4-11. INADEQUATE TRANSIENT RESPONSE.

NOTE: This condition should be checked by an oscilloscope at the output terminals of the supply, with the sensing terminals temporarily jumpered to the corresponding output terminals. None of the load current should be permitted to flow through any portion of the oscilloscope leads or the sensing leads.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Regulation and ripple are within specification and external sensing circuit is properly and firmly connected.	1.a. By-pass capacitor (B) open, or very low in value.	1.a. Replace
	b. Filter capacitor (AE) low in value.	b. Replace
	c. Failure in oscillation dampers (BF) &/or (AN).	c. Check for defective parts & replace any found low in value, open, or shorted.

NOTE

A brief transient during switching is normal, the measurement of transient response may be complicated by inductive transients of 1 to 50 microseconds duration due to lead inductance, etc., but since these are easily handled by means of local by-passing, they have no significance in determination of the transient response of the supply.

4-12. OSCILLATION.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Under constant load, output voltage varies at a cyclic rate (sawtooth or sine wave) of 200 cycles or more per second.	1.a. Defective diodes (CR109) (CR110) or resistors (C-D).	1.a. Replace
	b. By-pass capacitor (B) is open or of low value.	b. Replace
	c. Rate sensing capacitor (AH) or its circuit is open.	c. Replace

4-12. OSCILLATION.

SYMPTOM	POSSIBLE CAUSE	REMEDY
	d. Suppressor capacitor (AL) in amplifier is open or of low value.	d. Replace
	e. Suppressor capacitor (C5) on model CR 36-50 is open or of low value.	e. Replace
B. Under constant load, output voltage varies in "saw-tooth" manner at a frequency of 200 cycles or less.	2. a. Output capacitor (F) is open.	2. a. Replace
	b. Rate sensing capacitor (AH) is open, or of low value.	b. Replace
	c. Excessive capacitance in external load circuit.	c. If load contains capacitance equal to or greater than capacitor (E), special precautions are necessary. Check with NJE Corp. Engineering Dept.
	d. Excessive amplifier gain.	d. If the beta (current gain) of one or more amplifier transistors is 150% or more of the manufacturer's bogie value, the increased gain which results (particularly at high ambient temperature) could result in this type of oscillation. Replacement of the transistor is required.
	e. Failure in controlled rectifier firing circuit.	e. Check all transistors first. Then carefully examine all other parts of this circuit replace all parts found to be defective.
	f. see Par 4-11 (c)	

4-13. REGULATION CHECK. Because of the inherently slight regulation exhibited by this power supply, it is impractical to make a regulation check by observing a voltage measurement across the output terminals of the supply as the line or load is varied.

4-14. To accurately check the regulation, it is necessary to use an external DC differential voltmeter, or digital voltmeter. The voltmeter should have a full-scale range of 0 to 5 or 10 volts (5-0-5 with center zero, if available), since it will be used to measure only the difference between two almost equal voltages. The balance adjustment is used to bring the meter needle to approximately midscale before testing, so that the deviation above or below the normal output of the supply under test can be observed.

4-15. The dummy load is selected to draw full load current at the nominal output voltage of the supply. The difference between the voltmeter readings with the switch open and closed (allowing the needle to come to rest before reading) gives the static load regulation in volts.

4-16. FEEDBACK AMPLIFIER CHECK. There are several methods which can be used in checking the performance and condition of the feedback amplifier.

Except for individually removing the transistors for a check by means of a transistor test set, and making continuity and resistance tests on the circuit and components, all methods require the amplifier to be energized with the proper potentials under the conditions found in the power supply for normal operation. For this reason, it is simplest to test the amplifier in position in the supply, first making certain that its DC power supply transformer, rectifiers, diodes (CR109 and CR110) and resistors (C) and (D) are functioning properly. This can be quickly ascertained by checking the circuit voltages as indicated on the schematic diagram. Once this is done, the procedures given below can be used to check out the amplifier itself.

a. Voltage Check. The simplest and most rapid direct check of the amplifier is made by connecting a temporary jumper from the base of transistor (Q107) to the base of transistor (Q108), thereby balancing the amplifier input stage, and checking for balanced voltages on the two defective stages, and simple analysis will pinpoint the defective connection or component. Verification is then made by testing the component itself or repairing the connection.

b. Signal Tracing Check. Since there is an inherent amount of ripple at the input to the amplifier, this ripple signal can be used as a test signal for observing the amplifier performance with the aid of a test oscilloscope, (ignore any spikes in the waveform. Use only the basic ripple signal when making amplitude calculations) in the event that the ripple is too small for practical use, a small 60-cycle sine wave voltage of convenient amplitude (less than 1/4-volt) can be injected into the amplifier, applying it across the amplifier terminals on printed circuit board for convenience. Measurement of the ripple at the input to the amplifier, and at the output of each successive amplifier stage will provide an effective check of amplifier performance. The ripple amplitude measured across the bases (or input) of the second stage transistors (Q105 and Q106) should be 20 to 40 times the amplitude at the input to the first stage.

The ripple at the base of the next stage, transistor (Q104) should be 15 to 30 times the ripple at the input to the previous stage. The ripple at the output terminal of the amplifier should be roughly the same as the input to transistor (Q104). Radical departure from this set of conditions will point up a defective component or connection, which can then be isolated by inspection and individual test. Be sure not to overdrive the amplifier stages as it will cause misleading results.

c. Stability Check. A detailed check for improper drift and intermittent failure can be made by utilizing a test rip similar to that shown for precise regulation check in Figure 4-3. The voltage across the zener diode reference source (CR111) is "bucked out", and monitored by a 0 to 1-volt (or smaller scale if available) high impedance DC voltmeter (null balance voltmeter). Drift or random instability will be readily visible in this test. Output voltages of the successive amplifier stages and regulating diodes (CR109) and (CR110) can then be monitored in the same manner. When checking a given amplifier stage by this method, the output of the previous stage should be shorted, to prevent external voltage variations from reaching the stage under test. When installing a new transistor in place of one shown to be defective, the stability check should be repeated, to make certain that the trouble has been eliminated.

4-17 Procedure for Oiling the fan: The fan (if provided) may require oil if operated under extreme environmental conditions. The fan incorporates the latest electrical and mechanical advances in the motor design and offers reliable performance from 2 to 5 years under favorable conditions of temperature and vibration without the necessity of oiling. Its life is in inverse proportion to these factors. For example, at 110° F the fan may be expected to give reliable performance in excess of three years and at 40° F, reliable performance is extended beyond five years.

If the fan should be installed in areas of greater heat, or severe vibration, its life may be extended by periodic oilings (a small amount once per year) which is absorbed by the bearing. For this oiling procedure, an OIL INJECTOR is required which may be ordered from NJE Corporation. This OIL INJECTOR, will service from 15 to 20 FANS. For refills order Fan Lubricant NJE Part No. 020923 in 4 oz. can.

Procedure:

Step 1: Remove cap from end of OIL INJECTOR.

Step 2: Place needle at the center of circle marked on the Gold label.

Step 3: Position the needle at an angle of approximately 45° to the surface of the label and tangent to the perimeter of the circle.

Step 4: Pierce the label and the concealed self-sealing rubber cap located under the label.

Step 5: Insert the needle approximately 1/4"

Step 6: Depress the plunger of the OIL INJECTOR slowly to the next calibration mark which will allow 1/16" of oil to escape.

NOTE

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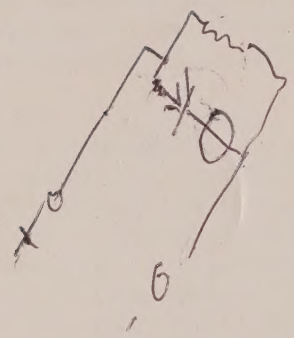
Rev: 6/3/63

It is better to give a little more oil than not enough, however, do not overflow the well. If the ambient temperatures are extremely hot, it may be advisable to oil more frequently to insure the optimum performance characteristics of the fan.



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